ADDRESSES AND COMMUNICATIONS.

THE APPLICATION OF BIOLOGY TO GEOLOGICAL HISTORY.*

By Charles A. White.

I have chosen the subject which has just been announced by the Chairman, because I have been so long identified with the geological and paleontological work of our country that I think you will naturally expect my retiring address to have reference to some subject connected with the biological history of the earlier ages of the earth. It has become customary upon occasions like the present for the speaker to select some subject relating to his own special lines of research; and it is often the case that such addresses are real contributions to science and records of its advancement, as indeed it is well that they should be; but after much hesitation I have decided that my remarks upon this occasion shall be of a somewhat opposite character. That is, I shall endeavor to show that certain prevalent ideas are erroneous, and, incidentally, how they have retarded rather than aided philosophical inquiry.

It is much pleasanter for one to record and announce the triumphs of long and patient research, and to show the evidence of a steady increase of knowledge in the branch of study to which he is devoted, than to point out the existence of errors in unexpected quarters. But it is well that we should pause occasionally in our labors and question the truth of every proposition upon

*Annual presidential address delivered at the Fifth Anniversary Meeting of the Society, January 24, 1885, in the lecture-room of the U. S. National Museum.

which we have been wont to act, and to inquire whether they will bear the light of rapidly increasing knowledge. I propose to-night not only to point out the insufficiency of the evidence which is relied upon to support some of the assumptions of paleontology, but to challenge the truth of some of the propositions which its leading men have been in the habit of treating as fixed laws of unquestionable and universal application, and to show that they are not in harmony with the facts of philosophical biology. I comprehend the danger that those who are not familiar with the leading principles of paleontology, hearing only a statement of the misconceptions which its votaries have fallen into, will be inclined to underestimate its fundamental truths, which are really unassailable. I wish to say, therefore, that I have no intention of treating my subject wantonly; and I shall be sorry to weaken the faith of any one in the general truths of a science which has done more than any other to broaden the minds of men as to the problems of animal and vegetable life; and which has a future before it, the brilliance of which is in no danger of being obscured.

The remarks which I am about to make refer mainly to certain errors, not yet entirely eliminated, which early obtained a foothold in paleontology, as a natural consequence of the biological opinions then prevailing, and which were inseparable from its stage of transition and growth. Modern paleontology, like the other sciences, has been a matter of growth; and errors once introduced have been found difficult to eradicate, even after an increase of knowledge has shown them to be such; and it is an unpleasant fact that our science, as it is now taught and practised, even by some of the best authors, is marred by some of its early defects.

The first and principal question which I propose to discuss relates to the chronological order of succession of animal and vegetable types, and their geographical distribution during their existence.

As aids to the correlation of the geological formations, fossils began early to be used. At first they were treated merely as tokens of the formations in which they occurred, without any reference to their character as representatives of formerly existing life; but it was soon perceived that by their use a systematic classification of the stratified rocks could be made. We now know that without their use we could not have obtained any adequate conception of geological history; and the present recognized scheme of the formations, or the geological scale, as it is sometimes called, could have never been devised. It is true that the order of succession of the few formations which may be favorably exposed in limited districts might have been made out by means of the lithological character of the strata alone; but the correlation of such limited groups of strata with those of other and distant districts would have been by such means impossible.

After the order of succession of the different groups of strata had been made out for certain regions and correlated with those of other regions, it began to appear that certain types of animal and vegetable remains characterized certain portions of the geological scale which was devised as a result of that correlation. That scale, which is the foundation of the one now in general use, was necessarily at first more or less defective and artificial. It has from time to time been much improved, and, although it is still imperfect, it is a marvellous monument of the results of inductive reasoning. Geology and biology have each come to the other's aid until not only has the foundation been substantially laid, but the structure itself is approaching completion in a perfect form.

In Europe, where geological science was first studied, and where it has ever since been prosecuted with remarkable energy, it was found that the chronological range of the types of fossils which characterize the respective formations is well defined. And when researches were extended into the adjacent parts of

Asia and Africa, the European standards were still found sufficiently exact for at least general conclusions. Even in Eastern North America the order of the formations and the types of the fossils which characterize them are closely like those of Western Europe, and in many cases the species are regarded as identical.

It was natural, then, that the conditions which were found to have formerly prevailed in those regions where geology was first studied should be held to have been the normal conditions for the whole earth. Such were the opinions formed by the earlier European geologists; and their successors still hold the European standard to be applicable to every region, and to every condition of climate which the earth has known. The leading idea which is embodied in this chronological scheme would, I think, be fairly illustrated by a diagram which may be constructed by taking such a section of the geological formations as is usually given in the text-books of geology, that of Dana's Manual for example, and projecting a series of circular lines from the boundary lines of each of its divisions and subdivisions. Let this series of circles represent approximately the time-equivalent of the geological column of formations and the assumed universal definition of each of its subdivisions.

It will of course be understood that such a diagram could not be intended to illustrate the time ratios of the different epochs, periods, and ages into which historic geology has been divided. It has been suggested only to illustrate the rigid character of the paleontological time-standard which European geologists have erected for themselves, and which they seek, with the consent of most of the geologists of other countries, to apply to the whole earth, even in minute detail.

It was formerly held that not only have all species of animals and plants been specially created, but that a majority of them became extinct during or at the close of each epoch; and that each period was closed with a universal catastrophe, by which

every living thing upon the earth was destroyed. Furthermore, that the whole earth, at the beginning of each successive period, was stocked anew by special creation, with all its forms of life; and that these forms were everywhere impressed with the type-characters peculiar to the respective epochs. Even after it became known that in numerous instances species and genera continued their existence from one period to another, it was still held that these were extra-limitary forms, and that their existence did not affect the exclusive character of the types of those animals and plants which were ordained to bear the chronological impress.

Accepting such a scheme of creation as this, it was natural to suppose that the types of animal and vegetable life which characterized each of the geological periods should be universal in its distribution, and strictly confined to the period for which it was specially created.

Although the doctrine of evolution is now accepted by every working naturalist, this idea of a successive series of narrow chronological horizons of universal extent, each characterized by its own peculiar types of organic forms, which are everywhere the same, and none of which exist in any other horizon, prevails to almost as great an extent as before. The later naturalists, it is true, based their views of this assumed constancy, not upon the idea of special creation and universal distribution in each period, as their predecessors did, but upon that of a progressive evolution, by distinct and world-wide steps, from pre-existing forms. The views which were held by the older naturalists were the result of a rational deduction from their own premises; but that similar views should be held by the naturalists of to-day is certainly unphilosophical. In accordance with the old views little opportunity was given for the variation of types, because, as they believed, all the species in which those types were expressed were sure to be extinguished at the close of each period, and they were to be succeeded by a newly-created series.

To the modern naturalist, a belief in the universal distribution, and narrow and rigidly restricted chronological range of organic types which characterize each successive epoch, implies that evolution has occurred in all instances in exactly the same mathematical ratio; for animal as well as vegetable forms; for aqueous as well as for terrestrial life; for the life of fresh waters as well as that of the seas; and under every environing condition of climate and of geological change. It implies the existence of some unknown and unexplainable law which, at the close of each epoch, required the utter and speedy extinction of exactly such types as had specially characterized those epochs, even if the physical conditions under which they had formerly existed had continued the same. That such ideas do prevail among paleontologists at the present time one has abundant proof in their published writings.

In Europe it was found that during the successive geological epochs certain types of plants and vertebrate and invertebrate animals all lived simultaneously; and the actual and relative rate of progress of evolution of the types in each of these great biological divisions, seeming to be a natural one, was regarded as under the influence of some cosmical law which necessarily made that rate uniform for the whole earth. When, therefore, even a single type, whether of plants or vertebrate or invertebrate animals, such as is known to characterize any European group of strata, has been found in any other part of the earth, it has been customary to hold that the animal or plant, as the case might be, which is represented by that type, existed simultaneously with its European congeners. Although the folly of relying upon such slender evidence has again and again been shown, it is not uncommon to see it presented in important paleontological publications with all the force that such words as "certainly," "undoubtedly," "unquestionably," &c., can give it.

I have made the foregoing statements, first, to call attention to the existence of the erroneous views which I have indicated; and, secondly, that they may serve as a suggestion of the reason

why they have obtained a foothold. I am confident that if the geological scheme had yet to be devised upon the basis of the advanced knowledge which naturalists have now acquired, it would be free from the defects which I have mentioned. In fact, it seems that these defects are due to the erroneous biological views which naturalists formerly entertained; and that they have remained solely because it is so difficult for men to free their minds from impressions which have once become firmly fixed, even after their fallacy has become apparent.

These errors have by no means escaped the attention of leading naturalists; and several years ago Prof. Huxley proposed the term "homotaxis" to express the existence of close biological relationship between formations in different parts of the world respectively, which might not, or could not, have been contemporaneously deposited. In using this term instead of "equivalent," "synchronous," &c., as has usually been done in relation to formations in separate regions which contain closely similar faunas or floras, one does not thus commit himself to any opinion as to the actual geological age of such formations, but only to the fact that the forms of life were similar when and where those formations were respectively deposited. Professor Huxley's idea may be represented graphically by superimposing upon the diagram which I have suggested a complementary series of lines, much as isothermal lines are superimposed upon a map with its lines of latitude. But to express the present state of our knowledge, these complementary or isotaxial lines must be sadly broken and fragmentary.

This idea of homotaxy necessarily has reference to some acknowledged standard of the order in which the geological formations have been deposited; and in using the term I shall of course have reference to that which is in general use, which is practically the European standard.

Various authors have shown, not only that many formations have been found in different parts of the world to be homotaxi-

ally related to each other by their respective faunas and floras which certainly were not contemporaneously deposited, but also that many foreign formations contain faunas which respectively embrace homotaxial representatives of two or more European formations. After I had selected the subject, and written out the greater part of these remarks, the address of Mr. W. T. Blanford and the article of Mr. J. Starkie Gardner, read before the British Association for the Advancement of Science, at Montreal, reached my hands. I find from a perusal of them that both of those gentlemen have so far anticipated much which I intended to say that I cordially recommend my hearers to read those productions. Both of them, especially that of Mr. Blanford, record some startling exceptions to the generally received rule that formations homotaxially related were of contemporaneous origin. I shall have occasion to refer to some of the cases of this character which they have mentioned, and I shall also cite other instances which have come under my own observation. First, I shall mention instances where there is apparent reversion of the chronological order of the formations, and afterward those in which a commingling in one formation of the characteristic types of two or more epochs occur.

Mr. Blanford, in his address, cites a considerable number of instances where the order of occurrence of faunal and floral types, according to the accepted chronological scale, is reversed. One of these instances occurs at the famous Pikermi beds, near the ancient city of Athens. These beds contain a rich mammalian fauna which is so characteristically Miocene that the French committee of the International Congress of Geologists specially mention it as of that age. Some of the species of the Grecian locality referred to are identical with those of some of the fully recognized Miocene strata of other parts of Europe. Now, Professor Gaudry found in the lowest of these Grecian beds which bear Miocene vertebrates several species of well-known Pliocene mollusca, and he also found that this bed in turn rests upon *a* "marine bed of undoubted Pliocene age."

A similar condition of things occurs among the Tertiary deposits along the southern base of the Himalayas in India, in what are known as the Siwalik beds. These beds contain a mammalian fauna which European paleontologists have unhesitatingly referred to the Miocene; but the geologists of the Indian survey have shown that they have many thousand feet of Miocene strata beneath them; and upon other grounds, also, they show that they cannot be of earlier age than the Pliocene.

Perhaps one of the most remarkable instances of the apparent reversion of the chronological order of the formations, as it is known in Europe, occurs in the great series of strata in India which is known as the Gondwána System. Mr. Blanford, in his address, gives an account of this remarkable case in detail. Certain of the beds of this system of formations contain a fauna which paleontologists agree in classifying as Triassic. These Triassic beds are found overlying beds which contain a Rhætic flora, or one which has its homotaxial representative in Europe between the Jurassic and Triassic; and these Rhætic beds are found to overlie those which contain a flora that paleobotanists refer with confidence to the Jurassic period. In the other cases mentioned, there is a reversion of two homotaxial epochs; but in this Gondwána System the reversion embraces three of them. That is, the order of all the three is reversed, so that the ascending order in India is the same as the descending order in Europe.

Again, it has been shown by experienced geologists that in Australia there are beds which bear a flora that paleobotanists declare to be typically Jurassic, and which are interstratified with marine beds that bear an abundance of characteristic Lower Carboniferous molluscan species. And, furthermore, that these beds are overlaid by a fresh-water formation which has been referred with confidence to the Permian period.

Coming to our own country, the most remarkable case of the reversion of the order in which the faunal and floral types are

found to characterize the European formations is found in the Cretaceous series of the valley of the Upper Missouri river. Here we have a series of strata which has been held to represent the European Cretaceous series from the Gault to the Upper Chalk, inclusive. In the lower division of this American series there has long been known to exist a flora which, when it was first discovered, was referred by the best authority to the age of the Eocene Tertiary. Even so late as the past year, Mr. J. Starkie Gardner has expressed the opinion that these plants are more likely to be of Eocene age than earlier. Now the strata containing this assumed Tertiary flora are overlaid by a series, several thousand feet in thickness, which contains an abundance of marine types that correspond with those of the Cretaceous of Europe. Indeed, several of the species are regarded as identical; and the types embrace reptiles, fishes, and cœlenterata, as well as all the classes of mollusca. Then, resting upon this series, and its Atlantic border equivalent, we find the whole Tertiary series, at least up to the close of the Miocene. Furthermore, a considerable number of these American Tertiary forms are usually regarded as identical with European Tertiary species. It would thus seem that both the stratigraphical and concurrent paleontological evidence are decidedly against the Tertiary age of that flora, and in favor of its Cretaceous age, notwithstanding its homotaxial relationship to the Tertiary flora of Europe.

The commingling of types in one formation which, in Europe, respectively characterize two or more separate formations, is a matter of not uncommon occurrence in America and other parts of the world. These cases occur where the order of the formations seems to agree well with that of the accepted European standard; and they apparently merely show that the types referred to began their existence earlier, or continued it later, as the case may be, than they were known to have done in Europe. In the other cases the discrepancies are seen to occur as between marine faunas on the one hand, and land faunas and floras on the

other; and those discrepancies amount to an actual reversion of the usual order. In the cases which I shall now mention, however. the discrepancies consist in either the actual or relative earlier introduction, or later continuation, of certain types among both marine and continental faunas and land floras, than is required by the European standards. In these latter cases there is of course a confusion of homotaxial relationship, of the formations which contain the commingled types, with other formations; but there is not necessarily any reversion of the order of occurrence of the types, as there is in the cases already mentioned.

I ought not in this connection to omit mention of the so-called colonies of Barrande, in Bohemia, which, as he contended, bear a marine Silurian fauna, alternating with strata which bear a Primordial one. But as the truth of Barrande's position has been seriously questioned, I need not discuss it in these remarks.

Even after what we have seen of the history of the received opinions concerning the synchronism of formations, it is still a somewhat remarkable fact that, although the blending of the faunas of certain formations into each other by the commingling of types, which are regarded as characteristic of each respectively, has been so long known and so often demonstrated, that the idea of universal restriction of types to narrow time-horizons should be so persistently held. Indeed, the fact that such a commingling of types as I have referred to has been so well recognized that it has made its impress upon the terminology of geology. Thus the term Permo-Carboniferous has long been used in America to designate strata which partake of both Coal-Measure and Permian characteristics; and the same term has been applied by Dr. Toula to strata which bear a similar fauna on the island of Spitzbergen.

The terms Cretaceo-Jurassic and Cretaceo-Tertiary have been respectively applied to New Zealand strata for obvious reasons. The former term has also been applied to Chilian strata by Darwin; and the latter, (but erroneously, I think,) to the Lara-

mie Group of our own country. Mr. Gardner would even extend the application of this latter term so as to embrace all that series of strata from the Dakota Cretaceous to the Laramie Group, inclusive. These terms, and the instances I have given of their application, are quite sufficient to show the existence of the facts to which I have called your attention. But the following instances of the early introduction and late continuance of certain important types are of especial interest in this connection.

From strata in Northwestern Punjab, India, which are by all geologists admitted to be of Carboniferous age, a remarkable collection of fossils was made which contained specimens of a species of Ammonites. Upon the announcement of this fact its truth was not only questioned by European paleontologists, but some went so far as to deny the possibility of the association of that genus with a Carboniferous fauna. Afterward the well-known paleontologist Waagen visited the locality and himself collected there specimens of *Ammonites*, *Ceratites*, and *Goniatites*, all associated together in the same layers with characteristic Carboniferous forms.

That *Goniatites* should be found in Carboniferous strata was to have been expected; but if the *Ceratites* and *Ammonites* had been found separately and unassociated with any other fossils, no European paleontologist would have hesitated to refer the one to the Triassic, and the other to the Cretaceous. In fact, Dr. Waagen has placed the Ammonite referred to under a generic group which is an especially characteristic one among Cretaceous faunas. This instance of the commingling of types which are characteristic of different periods is a remarkable one in all respects, and especially as showing the very early differentiation of even subgeneric forms, which are generally believed not to have existed until a much later period. Confirmatory of the fact of this introduction before the close of the Paleozoic age, of types which are especially characteristic of the Mesozoic, Professor Heilprin has announced the discovery of an Ammonitic form among a characteristic Carboniferous fauna from Texas.

The commingling in New Zealand strata of types which are usually found to characterize separate formations has already been referred to, but in this connection I also wish to mention the reported discovery in those islands of *Belemnites*, *Belemnitella*, and *Plesiosaurus* in strata which have usually been classed as Tertiary. There seems to be little reason to doubt that this is an instance of a natural transition from the Cretaceous to the Tertiary, so gradually accomplished that it cannot be said where the one ends and the other begins.

A similar survival of Mesozoic types into an epoch, the strata of which bear otherwise the fullest evidence of homotaxial relationship to the Eocene Tertiary, occurs in California. Here there is found a species of Ammonite associated with numerous genera which all paleontologists have agreed in regarding as characteristic of the Tertiary. The series of strata which contains this belated Ammonite is some ten thousand feet in thickness, the lower part of which is homotaxially related to the Cretaceous, and the upper part is similarly related to the Tertiary, with the exception just mentioned. Still, this series of strata has every appearance of having been produced by continuous sedimentation, and of presenting an intercommingling of Cretaceous and Tertiary types through the greater part, if not the whole, vertical range of the series.

In the cases which have just been mentioned, the continuation of ancient types among those of later origin, or of more modern characteristics, the comparison was made between the different members of one and the same fauna for the different portions of its existence; but in the case now to be considered, the comparison is to be made between continental faunas and floras. The case referred to is that of the Laramie Group. It will be remembered that in my address before this society last year I made some extended remarks upon this group, showing that it was deposited in a great inland sea of brackish and fresh waters. Comparison, therefore, is to be made between the aqueous fauna

of such a sea, and the land fauna and flora which existed upon its borders. I have upon several occasions called attention to the fact that brackish and fresh-water faunas have undergone far less differentiation during the lapse of geological epochs than marine faunas have. I cannot now contrast the aqueous fauna of the Laramie Group with any open-sea fauna, but, together with its contemporaneous flora and land molluscan fauna, it contrasts strangely with its contemporaneous land vertebrate fauna.

The aqueous fauna of the Laramie Group is mainly molluscan; and while the brackish-water forms show their relationship to the preceding Cretaceous marine fauna, the fresh-water and land mollusca are largely of types that now exist. The flora is also of a very modern character; but the vertebrate land fauna is largely Dinosaurian. I need not tell a paleontologist that here is a most remarkable mixture of types. The extraordinary biological character of this group will be still more conspicuously seen when I mention that I have collected the characteristic mollusca of this group where they were associated with Dinosaurian remains; and in the same series of layers I have also obtained numerous species of plants, several of which have by competent authority been identified with European Miocene species, and two of them with species now living in the United States. That is, we have evidence that a large molluscan fauna, and a luxuriant dicotyledonous flora, both containing species that we can with difficulty, if at all, distinguish from living forms, existed contemporaneously with great Dinosaurian reptiles such as have always been regarded as peculiar to the Mesozoic age.

The instances which I have presented demonstrate that in different parts of the world there are many and material departures from the European paleontological standard; but in no case have we seen that departure to be so great when marine formations are compared with each other as they are when formations containing a marine fauna are compared with those containing a continental fauna or flora. I therefore quite agree with those

who regard the marine faunas as much the most reliable indices of geological age.

During geological time the open sea has certainly afforded far greater uniformity of conditions for the existence and evolution of the different forms of life which it has contained than the land and fresh waters have done. Therefore, it is reasonable to conclude that, as a rule, the progress and ratio of the differentiation, evolution, and decadence among marine forms have been more uniform throughout geological time, and over greater areas, than has been the case with continental life. While, as we have seen, the ratio of evolution and decadence of marine types among themselves has not been so uniform as it has been assumed to have been by the European paleontological standard, such a ratio for the continental forms of life has often not only an extraordinary want of uniformity among themselves, but it is often at great variance with that of marine life.

Now it seems to me that the absence of a uniform ratio of evolution and decadence between marine, fresh-water, and land faunas and land floras, respectively, is just what we ought to expect when we consider the great variety of character of the various forms of life involved, and the great diversity of physical conditions under which they have existed. All that we yet know of ancient continental life points to the conclusion that the evolution of its various forms has been subject to frequent accelerations and retardations; and that, as a rule, they have been more subject to abrupt extinction than marine forms have. It is true, however, that some of the types among the continental faunas and floras which are now living have come down to us from very ancient times. It is also evident that a uniform rate of evolution of similar forms of continental life did not obtain in all parts of the world during the respective geological periods. An illustration of my meaning in this respect is afforded by our Cretaceous dicotyledonous flora already referred to. In America that flora had reached the European Tertiary stage long before the close of the Cretaceous period.

The instances which I have mentioned, besides many others which might be referred to, show that the confidence with which many paleontologists have decided upon the question of the synchronism of formations in widely separated portions of the earth, some of which are at most only one or two hundred feet in thickness, is quite unjustifiable.

I would gladly end here my arraignment of the unwarrantable positions which paleontologists have hitherto assumed, but I have yet to refer to others, especially to the custom of deciding upon the homotaxial relationship, or so-called equivalency, of formations upon insufficient evidence. Before the student of living animals and plants is prepared to decide in a satisfactory manner upon the forms which he is investigating, he requires not only a series of perfect specimens of his species, but also all that can be known of its anatomy and physiology, its habits and habitat, its associated forms, and its specific and generic relations. On the contrary, the paleontologist, as is well known, is confined to the study of such of the hard or skeletal parts of animals as may have escaped destruction by decomposition or other means; and the imprints or fragments of plants, mainly leaves.

One cannot cease to wonder at and admire the large amount of real knowledge which has been gained by the study of even such imperfect material as this. In fact, all that we know of the ancient life of the earth has been derived from this source; and by means of comparisons with related living forms we are often able, by the aid of a perfectly legitimate use of the imagination, to restore to a large extent the faunas and floras of long past geological periods. Encouraged by this success, and urged by the necessities of geology, paleontologists have assumed not only to decide upon the specific and generic identity of the forms represented by such imperfect material, but also to base upon it generalizations of the greatest importance in both geology and biology.

Every investigator knows how small a clue will sometimes lead to the unravelling of obscure problems in scientific research, and no one has more frequent occasion to give earnest attention to such clues than the working paleontologist. Indeed, some of his best results would often have escaped him if such clues had been disregarded. Such a use of even the most insignificant facts is perfectly legitimate; but I wish to refer especially to the practice which has prevailed of publishing what are ostensibly conclusions which have been reached from legitimate investigation, when in reality they are at best little more than mere surmises. I will give a couple of instances of this kind to illustrate my meaning.

In California and Western Nevada, where the country is mountainous and the rocks are much displaced and more or less altered, several isolated and limited exposures of strata have been found which contained a few fossil shells. At some of the localities half a dozen species are represented, but at some only one or two species. Most of these specimens are too imperfect to serve as the basis of even a satisfactory specific description; and none of the types presumably represented by them are of such a character as to give reasonable assurance of even homotaxial relationship with those of any European formation.

The most that can be said of this meagre fauna is that it is probably of Mesozoic age. And yet the equivalency of these rocks with the Jurassic of Europe has been confidently asserted, and broad generalizations have been based upon that assumption as to the age of mountain uplifts and other great geological events.

Again, there is in the western portion of the United States domain a formation which all geologists and paleontologists have agreed in referring to the Jurassic period. It is true that its invertebrate fauna is not full enough to afford entirely satisfactory evidence on this point, but the rich vertebrate fauna which

Professor Marsh has published from that formation has been accepted as conclusive. Furthermore, the position of the formation in relation to those which underlie and overlie it is confirmatory of the received opinion as to its Jurassic age. Notwithstanding this weight of evidence in the direction indicated, the paleontologist of the Canadian Geological Survey has, upon what I believe to be the mistaken identification of a comparatively small collection of imperfect and uncharacteristic fossil shells, referred the formation bodily to the Middle Cretaceous. When such a circumstance as this is possible it is certainly time we should examine well the grounds of our conclusions before we publish them to the world or base other results of our labors upon them.

While belief in the general applicability to all parts of the world of the chronological scale now in common use will probably never be seriously shaken, it is plain that we must abandon the idea that formations in widely separated parts of the world were necessarily synchronous in their origin because certain portions of their faunas or floras are similar. The custom has been to recognize a complete chronological scheme of the formations, of universal application, as already established, and to prosecute the geology of every part of the earth with the express view of making it conform to that scheme. But I submit that the geology of each of the large divisions of the earth ought to be studied independently, and untrammelled by preconceived notions of necessary conformity to a foreign standard. In my opinion, the time has not yet come for the construction of a complete and detailed chronological scale for the whole earth, and that it will not have fully arrived until the whole earth shall have been carefully studied.

If geology were studied in the different divisions of the earth with the ideas in view which I have indicated, its prosecution would be relieved of much useless labor, as well as freed from a

large proportion of the now prevailing liability to error. I do not wish to be understood as trying to discourage comparisons of the geology of different parts of the earth with each other. On the contrary, this ought constantly to be done; but what I wish to insist upon is that the study of each separate division of the earth should not be trammelled by a standard erected for another.

I have shown that the study of geology and paleontology has always been interdependent; but among certain geologists and paleontologists, respectively, there has been manifested a disposition to pursue the study of each branch separately, if not independently. A large part of the paleontological work which has been published has been done by men who have made no systematic study of field geology, or none in connection with their paleontological work. Much of their work has evidently been done in the belief that the paleontologist can sit in his study and fix with precision the geological horizons and the order of succession of the formations from which every collection submitted to him may come. If a difference of opinion in this respect has arisen between the field geologist and the paleontologist, each has contended for the truth of his own position, and each has often been shown to be in error.

It is therefore evident that the field geologist and paleontologist must work in concert. Indeed, the field geologist who ignores the use of fossils, as some have affected to do, is sure to burthen science with the results of worthless work; and the paleontologist who does not go to the field and study there the formations from which his fossils have been obtained is sure to produce results of work which will be worthy of the condemnation of both geologists and biologists.

But I am confident that there is a better day near at hand for the science to which so many able men have devoted their lives; and that the evils to which I have called your attention are already

passing away, and will soon be entirely of the past. When we remember what rapid strides have been made in all the branches of natural science within the memory of even the youngest workers, we have reason to anticipate a future for all those branches which will equal our most extravagant desires.